*November* 27, 1884.

Mr. J. EVANS, Vice-President and Treasurer, in the Chair.

In pursuance of the Statutes, notice was given from the Chair of the ensuing Anniversary Meeting, and the list of Officers and Council nominated for election, was read as follows:—

*President.*—Professor Thomas Henry Huxley, LL.D.

*Treasurer.*—John Evans, D.C.L., LL.D.

*Secretaries.*— { Professor George Gabriel Stokes, M.A., D.C.L., LL.D.
Professor Michael Foster, M.A., M.D.

*Foreign Secretary.*—Professor Alexander William Williamson, LL.D.

*Other Members of the Council.*—Captain W. de Wiveleslie Abney, R.E.; William Henry M. Christie, Astron. Royal; Professor George H. Darwin, M.A., F.R.A.S.; Warren De La Rue, M.A., D.C.L.; Robert Etheridge, F.R.S.E., F.G.S.; Sir Frederick J. O. Evans, K.C.B.; Professor William Henry Flower, LL.D.; Professor George Carey Foster, B.A.; Sir Joseph D. Hooker, K.C.S.I.; Professor Henry N. Moseley, M.A., F.L.S.; Hugo Müller, Ph.D.; Captain Andrew Noble, R.A., C.B.; the Lord Rayleigh, D.C.L.; Professor J. S. Burdon Sanderson, LL.D.; Lieutenant-General R. Strachey, R.E., C.S.I.; Professor J. J. Sylvester, M.A., D.C.L., LL.D.

Professor Alexander Stewart Herschel and Professor Charles Stuart Roy were admitted into the Society.

The following Papers were read:—

I. "Notes on the Microscopic Structure of some Rocks from the Andes of Ecuador, collected by E. Whymper. No. V (Conclusion). Altar, Illiniza, Sincholagua, Cotocachi, Sara-urcu, &c." By Professor T. G. Bonney, D.Sc., F.R.S. Received October 29, 1884.

The number of specimens described in this concluding paper of the series is not great, although more mountains are represented than on any other occasion. Four out of the five mountains enumerated above are volcanic, and, as will be seen, their rocks all belong to the andesite group. Sara-urcu, however, consists wholly of metamorphic

The Royal Society is collaborating with JSTOR to digitize, preserve, and extend access to *Proceedings of the Royal Society of London.* www.jstor.org

rocks, and thus lies outside the volcanic zone. I am again indebted to Mr. Whymper for the interesting general notes which are prefaced to the lithological descriptions.

*Altar.*

"This mountain is probably the fifth in rank of the Ecuadorian Andes, and according to Messrs. Reiss and Stübel is 17,730 feet high. Owing to long continued bad weather I could neither ascend nor measure it. It is about 40 miles E.S.E. of Chimborazo, and lies S. of Cotopaxi, having nearly the same longitude.

"In the older maps of Ecuador this mountain is sometimes called Los Collanes, and there is a valley leading from it in a westerly direction still bearing that name. I encamped at the head of this valley close under the main mass of the mountain (12,540 feet) and in the neighbouring valley of Naranjal (13,050 feet) for five days, and experienced during the whole time a succession of storms of wind, rain, hail, and snow, and such observations as could be made were obtained with much difficulty.

"The peaks of Altar have been considered by previous travellers to fringe the edge of a *broken-down* crater. Appearances are in favour of this supposition, though there does not seem to be any distinct evidence in support of it. The valley of Collanes leads away from the open, or broken-down side, and if it were followed up to its furthest extremity the traveller would find himself in a vast *cirque* filled with glacier, and bordered by peaks rising to heights 4,000 feet above his level. The valley of Collanes is not at present occupied by such masses of *débris* as we should expect to find if there had been any great convulsion which wrecked the western side of the crater.

"The highest peak of Altar is situated at the head of the valley of Collanes, on its left bank or southern side. On the opposite side of the crater (*i.e.*, on the right bank or northern side of the valley) there are several points only slightly inferior in elevation to the highest peak; but at the extreme head of the valley (*i.e.*, the eastern side of the crater) the edge of the rim of the crater is considerably lower than upon its north and south sides. The summit of this depressed part might, in my opinion, be reached from the interior of the crater, but the highest point could not. Its face towards the interior of the crater is as steep as the most abrupt part of the Eigher in the Bernese Oberland, and it is covered with small hanging glaciers. From the exterior of the crater the summit of this peak may perhaps be reached. My assistant, J. A. Carrel, reported favourably upon it, stating that there was a large glacier upon its southern side (which was unseen from the valley of Collanes), and he brought back from the highest point he reached (which was probably about 3,000 feet above our camp) the specimens A and B, taken *in situ*, and C, a loose

fragment. My second assistant, Louis Carrel, who was sent simultaneously to report upon the northern side of the second summit, brought back from the highest point he reached (about 14,500 feet) the specimen D." (E. W.)

A. This is a very dark compact rock, with fairly numerous specks of a greyish felspar, and with occasional minute vesicles. Under the microscope the ground-mass is found to be a glass, in itself almost colourless, but so crowded with opacite as to appear almost opaque with low powers; in fact its true structure can only be seen in very thin sections and with high powers. In this also minute crystallites probably of a plagioclastic felspar abound. Crystals of the same mineral of larger size are also very frequent; the larger are often about ·02 inch diameter, or even more, but the smaller and more frequent are not much more than one-tenth of that size. The larger crystals resemble in all respects those so often described, and are probably labradorite; the smaller are lath-shaped, and appear to have smaller extinction angles, and so may belong to one of the species containing more silica. Besides these there are a fair number of crystals of augite, some very well characterised, some containing enclosures of brownish glass. There are also one or two crystalline grains, partly replaced by a secondary dark-brown mineral, which appear to me to be not improbably olivine. There are also some small round specks of a gummy-brown isotropic mineral. It is possible that these are amygdaloidal and a variety of palagonite. From the above description it is evidently a little difficult to decide whether to retain this rock in the augite-andesites or to term it a basalt, and a chemical analysis would be necessary to settle this point. It is evidently near the border line, but I prefer on the whole to class it with the augite-andesites.

B. This specimen is a rough scoriaceous lava, weathering a dull reddish to brownish colour; it is full of small cavities, but in the more compact portions little crystals of light-coloured felspar are common. It is evidently so closely related to A that, as the specimen is in a less favourable condition for examination, I have not had it sliced. Of the two I should more unhesitatingly name this one an augite-andesite.

C. A very dark compact rock containing fairly numerous specks of a light-coloured felspar. The specimen is a fragment of prismatic form, having six sides pretty clearly, though unequally, defined. Examined microscopically the ground-mass is seen to be composed of a mass of felted microliths of plagioclastic felspar (probably to a large extent oligoclase), with granules of augite and of iron peroxide, most of which are in all probability magnetite. The structure in short is one common in andesites and allied varieties of "trachyte." Probably a little glass remains unindividualised, but I have not been able to satisfy myself on this point.

Scattered in this, and belonging probably to an earlier stage of consolidation, are the following minerals: (*a*) plagioclastic felspar, often about ·02 to ·04 inch diameter, probably, as usual, labradorite. Many of these have a broken and corroded aspect, this being more than usually conspicuous; (*b*) magnetite; (*c*) grains of a pyroxenic mineral. It is rather difficult to decide upon the species of the last; some of the grains are prismatic in form, but others have a more or less rounded outline. The cleavage seems imperfect. The mineral is clear, colourless, and of a rather frosted texture. The imperfection of the external form and of the cleavage makes it difficult to obtain clear indications of the crystalline system. Brilliant colours are given with crossing Nicols. It is not impossible the mineral may be monoclinic, still some results suggest the probability that it is orthorhombic. If an augite, it is rather abnormal, but we must be prepared for the presence of some other magnesian silicate, such as olivine or (more probably) enstatite. Be this as it may, the rock itself is a member of the augite-andesite group.

The rock D, from the north side of Altar, has a different aspect, being (like some already described) a reddish-grey trachyte, studded with crystals of rather glassy white felspar, roughly about ·1 inch diameter, and containing some minute vesicles. It has not yielded a very good slide. The ground-mass appears to be a clear glass, with numerous lath-like crystallites of felspar, but is so thickly crowded with ferrite and opacite, especially the former, as to be all but opaque except in the thinnest part of the section. In this ground-mass are scattered crystals of the usual plagioclastic felspar, and a pyroxenic mineral; some of this is monoclinic augite, but I think a few grains are certainly orthorhombic. Thus the rock is an augite-andesite, probably containing some hypersthene.

*Illiniza.*

"This mountain is probably the seventh in rank of the Ecuadorian Andes, and is the most southern of the four which lie (approximately) in a line.* It bears exactly due west of Cotopaxi, at a distance of about 20 miles. The road to Quito passes over the ridge which in a manner connects the two mountains. According to Messrs. Reiss and Stübel its height is 17,405 feet. On February 9, 1880, I reached the height of 17,023 feet on the south side, upon June 9, 1880, the height of 16,922 feet on its north side, and in the middle of May, my two assistants, Louis and J. A. Carrel, gained the summit from the north.

"The summit of Illiniza proper (there is a secondary peak on the northern side which is termed Little Illiniza) is exceedingly sharp,

* The four (commencing from the north) are Pichincha, Atacatzo, Corazon, Illiniza.

and at the time of my partial ascents the crests of the ridges leading to the highest point were coated fantastically with overhanging cornices of snow and small glaciers. On the south side, such rocks as could be seen *in situ* were a highly decomposed trachyte, which externally bore an almost chalky-white appearance, with veins and patches of lilacs and purples pervading it. On June 9, 1880, previous to attempting to ascend the mountains from the north, I encamped against a huge block of trachyte (15,446 feet), from which I took the specimen A. The Carrels, on their ascent, brought from the highest rock visible, *in situ* (close to the summit), the specimen B, and also four specimens of *débris* from the same spot." (E. W.)

From Illiniza five specimens have been examined; one from the site of the camp on the north side, and four from the summit, whereof one was from rock *in situ*. The first, A, is a moderately dark-grey, slightly vesicular "trachyte," containing crystals of glassy felspar sometimes (though rarely) nearly $\frac{1}{4}$ inch diameter, and some small flakes of black mica. A slice shows a base of clear glass thickly studded with acicular microliths (probably in part at least felspar) and granules of ferrite and opacite, so that when viewed with low powers it has a brownish-grey, finely granular aspect. In this ground-mass are scattered abundantly crystals of felspar varying from about ·1 inch downwards, together with very numerous lath-shaped crystallites often about ·004 long. The larger, as usual, appear to be closely allied to labradorite. They have often externally a worn corroded or broken look; internally they vary much; some are nearly clear, many have a few microlithic enclosures or spots of brown glass, a few are very full of irregular patches of the latter; zonal banding is often well exhibited. There is a little brown mica, some very characteristic hornblende, also brown-coloured, and a considerable quantity of granules and small crystals of a pyroxenic mineral, some of which, I think, are monoclinic augite, but others appear to be orthorhombic, and are probably hypersthene. There are the usual granules of magnetite, and some minute colourless crystallites which may be apatite. The rock accordingly is a hornblendic augite-andesite, containing also some mica and hypersthene.

The specimens from the summit are more scoriaceous and of a redder colour. One (*débris*) is more compact than the others, and of a dull brick-red colour, spotted with small crystals of whitish felspar. The others are very similar, being a rough scoriaceous rock, containing felspar crystals similar to but not quite so large as those of the rock described above. In one is an irregular branching tube or vein, coated with a dull greenish or brownish glass, which I suspect to be a fulgurite. I have only had a slice cut from the specimen broken from the rock *in situ* (B). It is not in a good condition for examination, but consists, so far as I can make out, of a ferrite-stained glass, con-

taining crystals of the usual plagioclastic felspar, with a ferruginous mica, grains of hematite or magnetite, and one or more pyroxenic minerals, of which it is difficult to decide the species. The rock is an andesite, but perhaps it is safest only to prefix the epithet micaceous.

*Sincholagua.*

"This is probably the tenth in altitude of the Ecuadorian Andes,* and is situated about north-north-east of the cone of Cotopaxi at a distance of 11 miles, and lies nearly east of the town of Machachi (whence it is visible) at a distance of 13 miles. The culmination of this mountain is a long ridge, rising at its highest point into a very sharp tooth, to the summit of which we ascended, but were prevented whilst there from taking any observations by the occurrence of a severe thunderstorm. We made a precipitate retreat, remaining only long enough to secure a couple of specimens." (E. W.)

One of these, a portion of the actual summit, is a compact dark-coloured rock, with a slightly rough fracture, containing numerous small crystals of whitish felspar, generally not exceeding ·1 inch in the longer diameter. Under the microscope, the ground-mass is seen to be a felted mass of minute elongated crystallites, probably felspar, and of specks of opacite; there is probably a residual glassy base, but so numerous are the crystallites that it is by no means easy to be sure. In this ground-mass are scattered larger crystals of plagioclastic felspar similar to those already described, augite, with probably some hypersthene (but it is not abundant), and magnetite. The rock is thus an augite-andesite, probably hypersthenic ferous. The other specimen taken *in situ* from the summit peak, a little below the highest point, is so evidently a rock of similar character, that I have thought it needless to have a specimen prepared for microscopic examination.

*Cotocachi.*

"This mountain, though probably slightly inferior in elevation to Sincholagua (and, consequently, only eleventh in order of the Ecuadorian Andes), presents a much more imposing appearance than its rank would lead one to expect. It is distant 45 miles in a direct line from Quito, being a little east of north, and from that city forms a prominent object. From the closer towns of Cotocachi, Otovalo, and Ibarra, above whose level it rises 8000 to 9000 feet, at distances of $8\frac{1}{2}$ to 15 miles, it wears a noble aspect. Reiss and Stübel by the mixed merc. bar. $\Delta$ method made its height 16,293 feet, and by merc. bar. observations on its summit I found its elevation to be 16,301 feet. Its summit ridge has two principal points, the lower being about 180 feet below the higher one.

* Height, according to Reiss and Stübel, 16,365 feet.

"There is no regularly formed crater upon the south, west, or eastern sides of Cotocachi. I cannot speak of the northern and north-western sides, which I have only seen from comparatively low ground at a considerable distance.

"In the neighbourhood of the mountain Cotocachi the surface of the earth is more fissured than any other part of Ecuador. The district about Cotopaxi, to which I have adverted when speaking of that mountain, alone presents anything comparable to the extraordinary series of chasms which seam or star the soil in the central portion of the flat land of the Province of Imbabura. From below, the traveller is made aware of their existence by occasionally having to skirt their sides for several miles, in a direction, perhaps, the very contrary of that which he desires to take; but their full extent is only perceived when one looks down upon the flat land from a considerable elevation, and then it is seen that the whole country in this vicinity is fissured by earthquake cracks, often several miles long, and sometimes hundreds of feet across.

"This neighbourhood has experienced very severe earthquakes during the last few centuries, the most recent happening shortly after midnight on August 16, 1868. Several persons independently pointed out to me a fissure, which had opened on this occasion, not less than 5 miles long, and varying in width from a few yards to several hundreds of feet. This earthquake was an affair of a few seconds, and in that brief interval almost the whole buildings within 10 miles were ruined, and tens of thousands perished. The priest of Cotocachi town informed me that that place was totally destroyed—not a single house being left erect. At Ibarra (about 13 miles distant from the mountain), Señor T. Gomez de la Torre, the greatest landed proprietor of this region, informed me that there were lists extant showing that 20,000 persons perished in that town alone—a statement that is scarcely credible, as the town of Ibarra has not the appearance of a place with so considerable a number of inhabitants. Respecting the widespread havoc which was caused on this single occasion, there is not, however, any question. The towns of Otovalo and Cotocachi had well nigh been rebuilt; but, at the time of my visit, most of the public edifices of Ibarra still remained in ruins, including schools, the hospital, a convent, and six churches, besides the church of the Jesuits, the finest building in the town, and the most imposing edifice I saw in Ecuador." (E. W.)

From this peak two specimens have been brought by Mr. Whymper—one from the summit rock, another from about 200 feet below it. The former is a purplish-grey rock, containing small whitish felspar crystals, with a good many minute vesicles. These have made the preparation of a slice a rather difficult task, and it is not so thin as I could desire. The ground-mass, however, appears to consist of a glassy

base, containing minute crystallites, probably for the most part felspar, but perhaps also a pyroxenic mineral, with rods of opacite and with ferrite staining. In this occur crystals of plagioclastic felspar, not generally exceeding ·03 inch, agreeing in general character with those already described, but perhaps more frequently containing enclosures, and "dirty looking," together with a pyroxenic mineral. The crystals of this are not very characteristic, but I think both augite and hypersthene can be identified. The other specimen is a small, rather rounded fragment, of a darker and more vesicular lava than the last, but with the usual whitish felspar crystals. The ground-mass, except in the thinnest sections, is practically opaque, but in those it is seen to be a light brown glass studded with crystallites, as already described, and containing specks of opacite. There are the usual larger crystals of plagioclastic felspar, perhaps rather cleaner than in the case of the other rock, with crystals of a pyroxenic mineral, among which, I think, both the monoclinic and the orthorhombic species may be recognised. Thus both these rocks from Cotocachi appear to be hypersthenic ferous augite-andesite.

*Sara-urcu.*

"Few references to this mountain will be found in the works of previous travellers in Ecuador. Reiss and Stübel appear to have *seen* it, for in their list of altitudes they mention that they made its height 6,800 metres (15,748 feet) by Δ in the year 1871, but they seem to have been doubtful about their determination, and do not enter that or any altitude in their "*Tabla comparativa.*" They quote from Villavicencio, who in his *Geografia de la Republica del Ecuador* (p. 52) gives its height as "6,210 varas sobre el mar," upon which Messrs. Reiss and Stübel remark "es probable que estas alturas no son sino avaluaciones aproximativas ó reducciones inexactas; pero no resultados de trabajos originales" (reckoning the vara at 2·782 English feet, 6,210 varas are equal to 17,276 English feet).

"Villavicencio quotes from Velasco passages to the effect that this mountain is a volcano that formerly emitted fire and has latterly ejected ashes, which have produced consternation in Quito, from which city the mountain is distant 35 miles to the east. I give the original below.* The results of my observations show that the mountain is not a volcano; that it is only 15,502 feet high; that it cannot

* "Segun refiere el P. Velasco en su historia de Quito, este volcan ha arrojado llamas por dos veces; mas, en estos últimos años, ha arrojado gran cantidad de cenizas volcánicas, por Diciembre de 1843, i por el mismo mes, en 1856. La primera de estas erupciones duró dos dias, i puso en mucho consternacion á los habitantes de Quito, i á sus pueblos circumvecinos. La altura de esta montaña es de 6210 varas sobre el mar. . . . Está situado á 35 millas E. de Quito."—Villavicencis, pp. 52–53.

have emitted fire and ejected ashes; and that it lies to the east-north-east of Quito, at the distance of more than 40 miles.

"The examination and ascent of this mountain (which is the least in elevation of those which I explored) occupied a greater length of time and gave more labour than any other, excepting Chimborazo. It will be enough to state in these notes that as we proceeded to the east we travelled out of the volcanic region of the Ecuadorian Andes and entered the older formations, passing through dense vegetation, which for a time entirely obscured the rocks. We encamped several days under the first rock that we came across—a large projecting cliff of mica-schist, situated almost exactly upon the Equator, at the height of 12,000 feet above the sea, which bears the name *Corredor Machai:* and waiting until we could see Sara-urcu, which was almost perpetually enveloped in clouds, reached the summit at length on April 17, 1880. There was a rudely level ridge of some length at the summit, upon which a considerable amount of rock *in situ* was exposed, which left no doubt as to the nature of this mountain. The glaciers we traversed on the west of the peak possessed small but very distinct moraines, and from the moraine matter, which evidently had been borne from various rocks cropping up through the ice, I collected various other specimens of mica schists and quartz, but could not detect a single fragment of the characteristic rocks which you have described in connexion with the other mountains—the active and extinct volcanoes of the Equator." (E. W.)

The specimen from *Corredor Machai* is a rude flat slab of rock which, macroscopically, most resembles a rather fine-grained micaceous gneiss. The slaty formation is evidently due to a rough cleavage traversing the rock, on the planes of which a silvery mica has been rather largely developed. Under the microscope the specimen is seen to contain the following minerals:—A silvery mica in scales, up to ·03 inch long, probably a hydrous alkaline-mica; a dull green mica (or, perhaps, in some cases a chlorite), much less abundant; numerous granules of quartz, with rather even sides and rectilinear outline, a colourless mineral, sometimes rather dusty-looking from included granules of opacite. This appears to have two not very well marked cleavages (indicated often rather by a constancy in the direction of included mica-microliths), which gives with crossing Nicols rather "stronger" colours than quartz (to which it bears considerable resemblance). It is difficult to decide upon the true nature of this mineral—andalusite and kyanite are the two which suggest themselves—and as I can get no evidence of its being orthorhombic, I think it more probably a not very characteristic variety of the latter; there is apparently at one end of the slide a portion of a vein of a similar mineral in a less pure condition; the long-bladed crystals, so often characteristic of kyanite, do not occur. The structure also of the rock is perplexing;

it must undoubtedly be classed with the crystalline schists, but I suspect that the very marked schistosity is a secondary development due to crushing.

From the *débris* on the peak of *Sara-urcu* one specimen has been examined. It is a fairly fissile mica-schist consisting mainly of a silvery mica in rather small flakes, with apparently a quartzose or felspathic constituent. Under the microscope there appear to be two micas —one, far the most abundant, a rather light yellowish-green colour, the other colourless. There is a moderate amount of rather clear quartz, containing occasional small microliths, probably of the former mica, and very minute cavities. There is some calcite, which often includes a minutely granular earthy-looking material rather clustered together. The layers of mica exhibit a kind of foliation, but the actual flakes are often (though not always) athwart the layers; this, together with other indications in the slide, leads me to suspect that the rock subsequently to its foliation has been compressed in a direction making a considerable angle with the original foliation planes.

Another specimen is a rather friable schist, consisting chiefly of a dark green, or nearly black mica, with a finely granular green mineral, which I have little doubt is epidote; there is also a little of a silvery mica. A third specimen is a piece of a quartz vein, from a rock identical with the last mentioned. Three other specimens from Sara-urcu, one broken from rock *in situ* on the summit, were examined macroscopically by myself soon after Mr. Whymper's return, but have since been unfortunately mislaid. The summit rock appeared to me a rather fine-grained gneiss, containing quartz, felspar, dark mica, with probably a little chlorite and epidote. Another was a schist, in which I distinguished quartz, dark mica, and a silvery micaceous mineral resembling sericite. The third was a vein specimen from a rock corresponding with the last named. I remarked in a letter to Mr. Whymper at that time:—"These specimens prove the existence of true metamorphic rocks, which are in about the same condition as many of those in what is called the 'newer gneiss' series of the Scotch Highlands."

A specimen from the moraine on the west side of Sara-urcu has been examined microscopically. It is a dull-coloured rock, which consists of a micaceous mineral with silvery lustre, and a dark mineral in small grains, being evidently a rather minutely constituted member of the group of the spotted schists (fruchtschiefer). The lustrous aspect is visible on the faces of the rough divisional planes; on cross fractures there is little lustre, and the rock has a slightly friable aspect. Under the microscope, what we may call the ground-mass of the rock consists of films of a very pale brown, almost colourless micaceous mineral, felted together in wavy folia, and interspersed with numerous specks of ferrite and occasional small granules of quartz; in this are

little lenticular patches, some containing more or less of quartz and of a white mica, but in most the space is mainly occupied by two minerals —the one (probably the dark specks visible in the hand specimen) occurs in rather rounded grains, which are darkened by a dusty opacite and by minute specks of a yellowish mineral. It sometimes appears to exhibit a slightly "radial" structure, but often this is not distinguishable. It is not isotropic, though it only gives dull colours with the Nicols. Occasionally it appears to be bordered with small prisms of the mineral next to be described. This occurs in prisms of rather "bladed" aspect, commonly, as it seems, four-sided, often about ·02 or ·025 inch long, and about one-fourth to one-eighth the breadth. There is a clearly marked, though not frequent, basal cleavage, making a large angle with the sides. The mineral is a very pale greenish-yellow in colour, rather granular in aspect, contains occasionally enclosures of opacite, &c., and gives moderately bright colours with the Nicols. Though extinction takes place at a rather small angle with the sides of the prism, the mineral is clearly neither uniaxial nor orthorhombic. It is not unlike an epidote, but I do not think it belongs to this group; moreover, there is nothing in the macroscopic aspect of the rock to suggest the presence of epidote, the glimmering scaly mica and the rather lustrous spots of a black mineral being all that is visible with a strong lens. I suspect that these minerals are rather nearly related, and both belong to the group of anhydrous alumina silicates—varieties, perhaps, of fibrolite or kyanite. Unfortunately my collection is not well provided with specimens containing these non-alkaline alumina silicates, so that I am unable to give a more precise definition. The rock, however, evidently belongs to the "fruchtschiefer" group, and I should conjecture has come from rather high up in a metamorphic series, probably occupying a position above those already described.

It is then evident that, as Mr. Whymper asserts, Sara-urcu has no claim to be called a volcanic mountain. All the specimens which he has brought from it are metamorphic rocks. They do not, indeed, belong to the earliest types, such as the coarse gneisses of the Hebrides, but still they are greatly altered. Unless there were very clear evidence to the contrary, I should regard them as members of the Archæan series.* Humbolt ("Cosmos," vol. v, p. 44, Bohn's edit.) mentions the occurrence of "greenish-white mica-slate with garnets," at the foot of a "black trachyte," at Penipe, not far from the mouth of the Rio Blanco; further on, "at the hacienda of Guansce, near the shore of the Rio Puela," and probably below that schist, a granite of

* It will be remembered that in Bolivia and Peru the eastern (and here much the more elevated) chain of the Andes consists of sedimentary (silurian) rocks, the western (ill-marked) range being volcanic. See D. Forbes, "Quart. Jour. Geol. Soc.," vol. xvii, p. 7.

a middling grain, with light reddish felspar, a small quantity of blackish-green mica, and a great deal of reddish-grey quartz. Again, "further to the south and a little to the east of the road leading from Riobamba Nuevo (9483), . . . mica slates and gneiss everywhere make their appearance towards the foot of the colossal Altar de los Collanes, the Currillan, and the Parama del Antillo." From these and other instances, he concludes that the great volcanic mountains rest on a foundation of schists or gneisses.

*Tonalite or Quartz-diorite.*

This specimen was taken by Mr. Whymper from a boulder in the bed of the S. Jorge River, at the place where the ordinary track from Bodegas to Quito crosses the stream a little above the village of Muñapamba, about 1350 feet above the sea, and at the commencement of the ascent of the Pacific slopes of the outer range of the Andes. This was the only place where Mr. Whymper found any rock resembling a granite, and he nowhere saw it *in situ*. It is macroscopically a fairly coarse granite-like rock in which a whitish felspar and dark green hornblende are the more conspicuous minerals. Under the microscope it is seen to consist of the following minerals:—Felspar, which in the great majority of cases exhibits either zonal banding or polysynthetic twinning, and may, I think, be safely regarded as principally oligoclase; hornblende with well characterised cleavage and external angles; a brown mica, sometimes almost opaque, frequently in aggregated flakes; quartz in granules, as in a granite, containing many fluid-cavities from ·0001 to ·0003 inch, in which commonly are bubbles occupying about $\frac{1}{4}$ or $\frac{1}{5}$ of their volume, magnetite, or perhaps in some cases ilmenite, possibly a little apatite. The hornblende appears to have crystallised nearly simultaneously with the felspar, but perhaps a little earlier, the quartz last of all. The rock is in moderately good preservation. It has macroscopically and microscopically a considerable resemblance to the typical tonalite of the Adamello district.

*Granite.*

There is a small specimen of this rock of which Mr. Whymper writes:—

"At the town of Bodegas I found a specimen of granite in the possession of an old English resident in Ecuador, Mr. Wilson, who gave me a fragment from it. He told me that he had collected it *in situ* on the track leading from the town of Riobamba (9000 feet) to the village of Baños (5905 feet, R. & S.), but I could not learn at what altitude it was taken. The locality is in latitude a little north of the spot at which the last described specimen was collected, and is on the opposite side of the Andes, that is to say, on the Amazonian

slopes." The rock is macroscopically a rather coarse granite, not very well preserved. Microscopic examination shows that there is nothing exceptional in its composition. The felspar is a good deal decomposed, but orthoclase pretty certainly predominates, though a plagioclastic felspar is also present. There is a fair quantity of quartz (containing many cavities, decidedly smaller than those in the tonalite, which are usually empty) together with dark brown mica and green hornblende, and some magnetite.

*Addenda and Conclusion.*

The illustrious traveller Humboldt appears to have brought back specimens from some of the volcanoes visited by Mr. Whymper, and the results of an examination of these by Gustav Rose are given in "Cosmos" (vol. v, Bohn's edition). The latter refers the rocks of Rucu-Pichincha, Antisana, Cotopaxi, Chimborazo, Tunguragua, and those beneath the ruins of Old Riobamba to the fourth division of the trachytes, in which "the leading mass contains augite with oligoclase." Humboldt further states that he found hornblende in a separate or sporadic condition "in the rock of Pichincha," also, though not in large quantities, in the "trachytes" of Cotopaxi, Rucu-Pichincha, Antisana, and Tunguragua, along with "augite and oligoclase," but has only recognised it in two of the specimens from Chimborazo. The following table of silica percentages is also given (on the authority of St. Claire Deville) to which I have added those marked thus *.

| Name of volcano. | Structure and colour of rock. | $SiO_2$. |
|---|---|---|
| Chimborazo . | Semi-vitrified brownish-grey | 65·09 Abich. |
| | Semi-vitreous and black | 63·19 Deville. |
| | Crystalline, compact, grey | 62·66 „ |
| Antisana .... | Grey-black | 64·26 Abich. |
| | | 63·23 „ |
| | Vitreous grey* | 77·76 Vom Rath.† |
| | Vitreous greenish-grey* | 72·99 Teall.† |
| Cotopaxi .... | Vitreous and brownish | 69·28 Abich. |
| | Granulated | 63·98 „ |
| Pichincha... | Vitreous black | 67·07 „ |
| | Flesh-red* | 62·99 Vom Rath.‡ |
| | Dark* | 64·55 „ |
| Puracé ..... | Nearly bottle-green | 68·80 Deville. |

† Pitchstone west of Antisana.

‡ Of these two rocks one is "from the summit," the other from the crater; brief microscopical descriptions show that they are hornblende-andesites, with some augite; substantially identical with some I have described in Part I of these Notes.

The following analyses of the rocks from Chimborazo are also given by Humboldt, which I quote for comparison with the description given by myself in Part III of these Notes. The first of them very probably represents a rock nearly identical with that obtained by Mr. Whymper at 19,300 feet.

| | I. | | II. |
|---|---|---|---|
| $SiO_2$ ..... | 59·12 | .... | 65·09 |
| $Al_2O_3$ ..... | 13·48 | .... | 15·58 |
| $Fe_2O_3$ ..... | — | .... | 3·83 |
| FeO ..... | 7·27 | .... | 1·73 |
| CaO ..... | 6·50 | .... | 2·61 |
| MgO ..... | 5·41 | .... | 4·10 |
| $K_2O$ ..... | 2·64 | .... | 1·99 |
| $Na_2O$ ..... | 3·46 | .... | 4·46 |
| Loss ..... | — | .... | 0·41 |
| | 97·88 | | 99·80 |

I. Broken from narrow rocky ridge at 19,194 feet; S.G. 2·806 (Rammelsberg).

II. Specimen collected at 16,179 feet; S.G. 2·685 (Abich).

Certain of these specimens appear to have been re-examined by Dr. Artope, and described in an inaugural dissertation published at Berlin in 1872; but of it I have only been able to see an abstract in Leonard's "Jahrbuch," 1874, p. 93. In this is given the analysis of a specimen from Pichincha, which, as it is described as having a greenish-black hard ground-mass, must be rather different from any in my collection. It was collected at a height of 15,539 feet; the specific gravity was = 2·624.

| | |
|---|---|
| $SiO_2$ ..... | 62·347 |
| $Al_2O_3$ ..... | 17·324 |
| FeO ..... | 4·501 |
| MnO ..... | 0·036 |
| CaO ..... | 5·426 |
| MgO ..... | 3·603 |
| $K_2O$ ..... | 3·126 |
| $Na_2O$ ..... | 4·286 |
| $H_2O$ ..... | 0·129 |
| | 100·778 |

It will be remembered that the species andesine has been formed for the reception of those plagioclastic felspars in the volcanic rocks of the Andes, which were termed oligoclase by the earlier observers. Some

of these have been analysed by Vom Rath in "Zeitsch. Deutsch. Geol. Gesell.," xxvii (1874), p. 296, and from this I quote two examples—

| | I. | | II. |
|---|---|---|---|
| $SiO_2$ ..... | 58·15 | .... | 59·10 |
| $Al_2O_3$ ..... | 26·10 | .... | 26·10 |
| CaO ..... | 9·05 | .... | 8·35 |
| $K_2O$ ..... | — | .... | 0·50 |
| $Na_2O$ ..... | 6·70 | .... | 5·50 |
| | 100 00 | | 100·55 |

I. S.G.=2·647. Loss on heating 0·27. From a spherulitic obsidian; Antisana.

II. S.G.=2·620. Loss on heating 0·01. From a dark andesite, containing among larger constituents hornblende, some augite, and plagioclase. From the crater of Guagua Pichincha.

It is evident that this felspar contains more silica and soda, and less lime than normal labradorite, of which in Dana's table of analyses (see "Mineralogy," s.v. Labradorite) the greatest amount of silica is given as 55·8, while the $Na_2O$ more often lies below than above 5, and the CaO ranges from 8 to nearly 13, and rather usually exceeds 9 per cent. Still, as the name andesine is by no means universally accepted, and it is extremely difficult to say what constitutes a species in felspar, I have throughout designated these larger felspars in the Andes rocks as labradorite, with which in their optical characteristics they appear to correspond very nearly.

A comparison of this paper of Professor vom Rath's (which I had unfortunately overlooked when writing my notes on Antisana), with one by Professor Theod. Wolf in the "Neues Jahrbuch" (1874, p. 377) shows that the pitchstones examined by myself came from the same vicinity as that described by Professor vom Rath in the note to which I referred in Part II. Professor Wolf states that quartz-andesite (which it will be remembered does not occur in its normal condition in Mr. Whymper's collection) is found at Achupallas, on Antisana, and to the south of Riobamba, as well as at the volcano of Mojanda. It forms the whole hill of Achupallas (12,402 feet), and is largely developed on Antisana. He mentions among the localities Urcucuy and Tablarumi, and speaks of a wonderful perlite lava-stream as occurring on Urcucuy, a hill "im Paramo, nicht weit unter dem Antisana-kegel." It is, therefore, evident that the specimens of pitchstone brought by Mr. Whymper (obtained from a collector) came from this district, since they bear the label *Quebrada de Urcucuy*. Professor vom Rath gives an analysis of the glassy part of the rock (I), with a separate one of the spherulites (II).

| | I. S.G. 2·32. | II. S.G. 2·386. |
|---|---|---|
| $SiO_2$ | 77·76 | 77·01 |
| $Al_2O_3$ | 13·14 | 12·90 |
| CaO | 0·63 | 0·21 |
| MgO | — | 0·29 |
| $Fe_2O_3$ | 1·47 | 1·88 |
| Alkalies and loss | 7·00 | 7·71 |
| | 100·00 | 100·00 |

The silica percentage in the specimen which was examined for me by Mr. J. J. H. Teall was not quite so high, being = 72·99; its specific gravity was 2·337.*

As the descriptions of these rocks from the Ecuadorian Andes have had to appear separately, it may be convenient to conclude this series of notes by a brief summary in a tabular form of the volcanic products of which I have described the microscopic structures.

It will also serve to impress upon us the general uniformity of the rocks occurring in the district. This was so obvious to Mr. Whymper, that he deemed it needless to bring many specimens from the mountains which he visited in the latter part of his journey. Yet the area which they occupy is a large one. From Altar and Chimborazo, the most southerly pair, which lie on an E.S.E.—W.N.W. line, about 40 miles apart (passing by Carihuairazo) to Cotopaxi and Illiniza (on nearly the same parallel of latitude) is rather more than 60 miles. Next come Corazon, Sincholagua, and Antisana (also roughly on an east and west line, the first being not much less than 40 miles from the third). Passing northward by Pichincha (N.W. of Quito), we leave on the east, Cayambe, which is a few miles east of the longitude of Antisana, and finally reach Cotocachi, the most northerly volcanic summit, having traversed a zone whose extreme length cannot be less than 130 miles from N. to S., and whose greatest breadth from east to west must be about 40 miles.† If, as some think, volcanic rocks are but sedimentary deposits melted down, this general uniformity is rather remarkable.

* Zirkel ("Microsc. Beschaff," p. 448) says that he has not found free quartz under the microscope in the so-called augite-andesites, but I do not understand whether he includes among them the rocks mentioned by Professor Wolf as occurring on the west side of Antisana. The composition and structure of the pitchstones described above make the occurrence of dacite in the highest degree probable, but I have not myself noticed free quartz in any of the ordinary Andes rocks. I regret that by an oversight "former" was written for "latter" at the end of the article on Antisana. I consider the pitchstone of Urcucuy, as stated in the body of the article, to be more probably allied to dacite than to rhyolite.

† The mountains are thus grouped by Mr. Whymper (reckoning from north to south)—*Western Andes:* Cotocachi, Pichincha, Corazon, Illiniza, Carihuairazo, Chimborazo. *Eastern Andes:* Cayambe, Antisana, Sincholagua, Cotopaxi, Altar.

| Name of Volcano. | Pitchstone. | Hornblende-andesite. | Augite-andesite. | | | |
|---|---|---|---|---|---|---|
| | | | Ordinary. | Hypersthenic-ferous. | Hornblendic. | Micaceous. |
| Pichincha— | | | | | | |
| Crater of Guagua-Pichincha, with actual summit | .. | × | | | | |
| Rucu-Pichincha, with actual summit | .. | .. | .. | × | | |
| Other parts of the mountain | .. | .. | .. | × | | |
| Antisana— | | | | | | |
| Highest rocks (16,000 feet) | .. | .. | × | × | | |
| Antisanilla | .. | .. | × | | | |
| Guagra-ialina | .. | .. | × | | | |
| Urcucuy | × | | | | | |
| Other localities, west side | .. | × * | .. | × | | |
| Cotopaxi— | | | | | | |
| Summit | .. | .. | .. | × | | |
| Camp, 15,100 feet | .. | .. | .. | × | | |
| Chimborazo— | | | | | | |
| Highest rock (19,300 feet) | .. | .. | × | | | |
| At 18,400 feet | .. | .. | .. | × | × | |
| 17,300 „ | .. | .. | .. | × † | | |
| 16,000 „ | .. | .. | .. | × | | |
| 15,950 „ | .. | .. | × ‡ | × † | | |
| Carihuairazo— | | | | | | |
| Summit | .. | .. | × § | | | |
| Cayambe— | | | | | | |
| Summit | .. | .. | .. | .. | × ‖ | × ‖ |
| Pointe Jarrin | .. | .. | .. | .. | × | |
| Corazon— | | | | | | |
| Summit rocks | .. | .. | × | × | | |
| Altar— | | | | | | |
| Main peak at about 15,500 feet | .. | .. | × | | | |
| Second peak at about 14,500 feet | .. | .. | .. | × | | |
| Illiniza— | | | | | | |
| Summit | .. | .. | .. | .. | .. | × |
| Camp, north side, 15,446 feet | .. | .. | .. | .. | × ¶ | |
| Sincholagua— | | | | | | |
| Summit | .. | .. | × | × (?) | | |
| Cotocachi— | | | | | | |
| Summit | .. | .. | .. | × | | |
| About 200 feet below summit | .. | .. | .. | × | | |

* Contains also mica.
‡ Rather abnormal.
‖ Poor in augite.
† Hypersthene predominating.
§ Perhaps hypersthenic-ferous.
¶ Contains also some mica and hypersthene.